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# CENTRAL-NERVOUS-SYSTEM EFFECTS AS MEASURED BY REACTION TIME IN SQUIRREL MONKEYS EXPOSED FOR SHORT PERIODS TO EXTREMELY LOW-FREQUENCY MAGNETIC FIELDS

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Central-Nervous-System Effects as Measured by Reaction Time in Squirrel Monkeys Exposed for Short Periods to Extremely Low-Frequency Magnetic Fields.

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The U. S. Navy has current interest in electromagnetic radiation including the extremely low-frequency (ELF) region. The Navy has begun a major research effort to scientifically document any physiological effects which these fields can have on man and his ecology. This present experiment was designed to detect any acute instantaneous central-nervous-system effects resulting from exposure to an ELF magnetic field. Reaction-time measurements were taken on three squirrel monkeys for 37 one-hour daily sessions. No significant changes in these measurements were observed between control sessions and sessions in which the animals were exposed to 3 gauss at 45 Hz or to a field of 3 gauss at 7 Hz. Two other indices of performance, reinforcement ratio and efficiency ratio, were also unchanged. The small number of subjects does not permit a firm conclusion; however, the evidence indicates that the magnetic field did not produce a central-nervous-system response measurable by the technique employed in this study.


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# CENTRAL-NERVOUS-SYSTEM EFFECTS AS MEASURED BY REACTION TIME IN SQUIRREL MONKEYS EXPOSED FOR SHORT PERIODS TO EXTREMELY LOW-FREQUENCY MAGNETIC FIELDS

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## SUMMARY PAGE


### THE PROBLEM

Current Navy interest in electromagnetic radiation includes the extremely low-frequency (ELF) region, and the Navy has started research efforts to scientifically document any physiological effects which these fields can have on man and his ecology. The present experiment was designed to detect any acute instantaneous central-nervous-system effects resulting from exposure to ELF magnetic fields.

### FINDINGS

Reaction-time measurements were taken on three squirrel monkeys for 37 daily sessions. No significant changes in these measurements were observed between control sessions and sessions in which the animals were exposed to 3 gauss at 45 Hz or to a field of 3 gauss at 7 Hz. Two other indices of performance, reinforcement ratio and efficiency ratio, were also unchanged. The small number of subjects does not permit a firm conclusion; however, the evidence indicates that the magnetic field did not produce a central-nervous-system response measurable by techniques employed in this study.


## ACKNOWLEDGMENTS


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Experiments reported herein were conducted according to the principles enunciated in "Guide for Laboratory Animal Facilities and Care" prepared by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences - National Research Council.

## INTRODUCTION

Extremely low-frequency (ELF) radiation has long been an environmental factor within the proximity of heavy-power distribution systems. Some household appliances and industrial machines also generate significant ELF fields. The U. S. Navy has current interest in electromagnetic radiation including the ELF region and has begun a major research effort to scientifically document any physiological effects which these fields can have on man and his ecology. Some studies have indicated that neuromuscular reaction time may be affected by ELF fields.

König and Ankermüller (5) and König (4) measured reaction time in humans exposed to ELF electric fields. The reaction time appeared to be frequency dependent: Longer reaction times were recorded when the ambient electric field contained frequencies from 3 Hz to 6 Hz, and shorter times were recorded for approximately 9 Hz.

Friedman et al. (1) exposed human subjects to magnetic fields of 0.2 Hz. Their reaction times were longer for the sessions in which the field was on than for the control sessions. No effects were found at frequencies of 0.1 Hz.

Hamer (3) reported an extremely small reaction-time effect on human subjects exposed to ELF electric fields at frequencies between 2 Hz and 12 Hz. He did not consider the results to be conclusive and emphasized the need for further experiments to substantiate his results.

Gavalas et al. (2) observed a significant difference in interresponse times for monkeys exposed to a 7-Hz electric field. No significant changes occurred at 10 Hz.

The present experiment was similar to those previous ones in that it was directed at the instantaneous as opposed to the cumulative effect of ELF fields. The animals were exposed to a 7-Hz magnetic field to compare results with those reported by Gavalas et al. (2) who used a 7-Hz electric field. The reaction-time technique used in the present experiment was similar to that developed for use with monkeys by Stebbins and Miller (6).

## PROCEDURE

### SUBJECTS

Subhuman primates were chosen as subjects because their central nervous system is somewhat similar to that of man. The physical size of the experimental facilities was compatible with the cage space required for adult squirrel monkeys. One female (LE, 525 gms) and two males (D26, 920 gms, and A88, 710 gms) of this species, Saimiri sciureus, were selected for this experiment. Three years prior to this experiment these

animals had been trained in other experiments that required manipulation of apparatus in conjunction with a reinforcement schedule. In those experiments LE and D26 had been exposed to a high-intensity dc-magnetic field to which they reacted by regurgitating (7). This previous training was an asset in that the animals were quick to associate manipulation with reinforcement; however, subject LE, who had been trained to depress a lever for an extended period, had some difficulty adjusting to the much shorter times required by the present experiment.

## APPARATUS

As shown in Figure 1, the animals were confined to the magnetic field by a Plexiglas cage, 15 1/2 inches long by 15 3/4 inches wide by 18 1/2 inches high. This cage was placed at the center of a wooden chamber, 45 1/2 inches long by 22 1/2 inches wide by 22 1/2 inches high. An aluminum response lever 3/8 inch in diameter projected 3/4 inch into the cage through a hole 5 inches above the floor and centered on the rear wall facing one end of the open chamber. A 10-inch-square electroluminescent lamp hanging at one end of the wooden chamber, 35 inches from the cage wall, served as the stimulus light. Reinforcement consisted of Purina monkey chow pellets weighing 0.22 gm each. Each pellet was released from a dispenser mounted above the wooden chamber and then traveled by force of gravity through a plastic tube into the cage. The magnetic field was generated by a Helmholtz coil wound on the outside of the wooden chamber. Recording, control, and magnetic-field generating equipment were located in an adjacent room to prevent the animals from receiving extraneous audio cues that would affect their performance.

## METHOD

Prior to training, the animals were food deprived to approximately 85 per cent of their ad libitum body weight and maintained at this level throughout the experiment. In the initial phase of training, each lever depression immediately illuminated the lamp and simultaneously dispensed a reinforcement pellet.

Following acquisition of that response, the procedure was changed such that the lamp was not illuminated unless the lever was depressed for 5 seconds, and reinforcement was given only when the lever was released in the presence of the light stimulus. If the lever was not released within 3 seconds from onset of the light stimulus, the stimulus was automatically terminated and no reinforcement was given. The time from lever depression to presentation of the light stimulus was then varied (1 sec to 15 sec) to improve the animal's association of reinforcement with light stimulus rather than merely holding the lever down for a fixed period. On the seventeenth training session, this delay was fixed at 5 seconds for the duration of the experiment, and the reinforcement schedule was changed to be controlled by a variable-interval tape puller. The interval varied from a maximum of 52 seconds to a minimum of 2 seconds, with an average of 15 seconds. Due to incorrect responses and the lever-depression time requirement, the actual reinforcement rate generally averaged approximately one per minute.

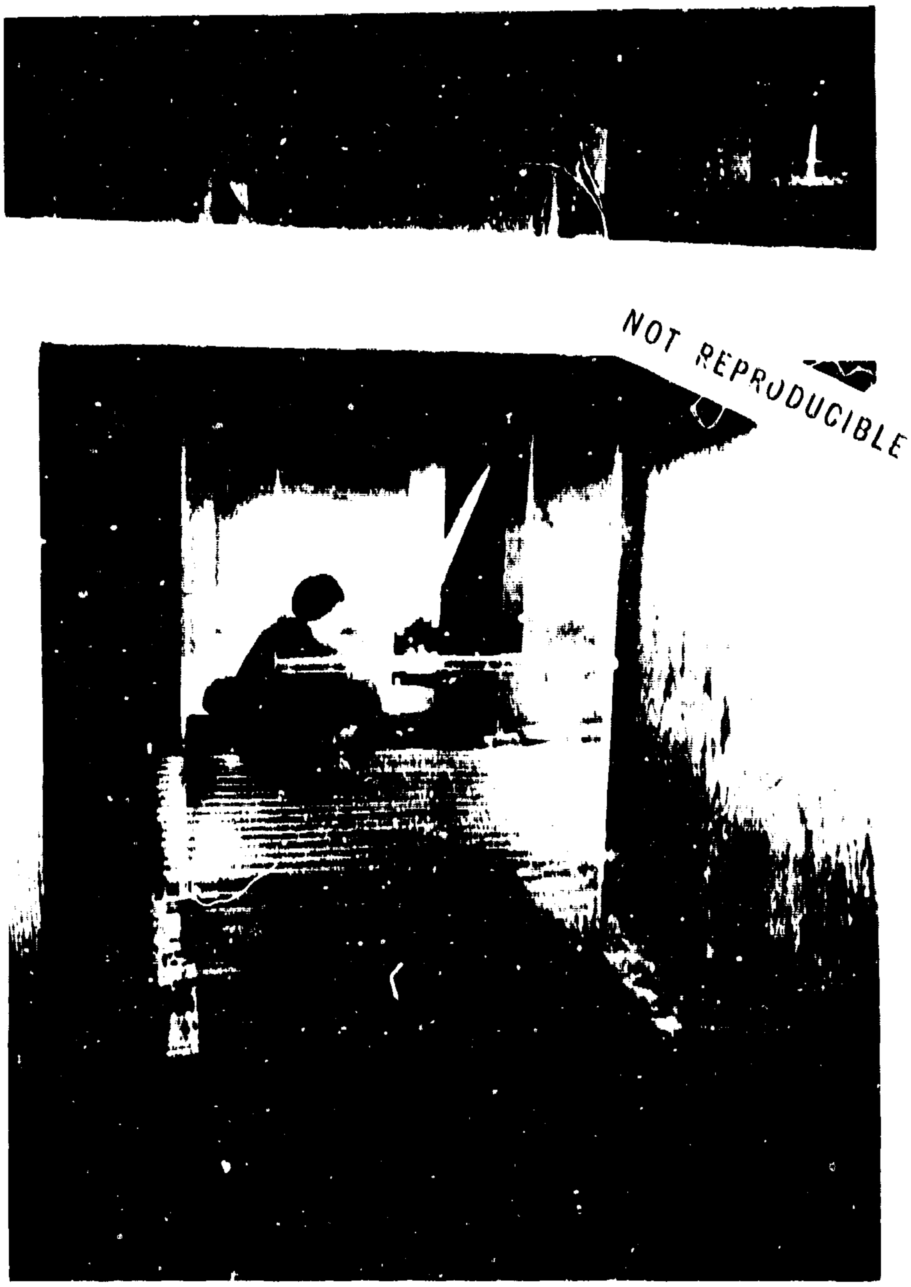



Figure 1

Subject is shown depressing operant lever inside the Plexiglas cage. The 10-inch-square electroluminescent lamp hanging at the far end of the wooden chamber served as the stimulus light. Each reinforcement pellet was released from a dispenser mounted above the wooden chamber (slightly out of view in the figure) and then traveled by force of gravity through a plastic tube into the cage. The magnetic field of 3 gauss was generated by a Helmholtz coil (not visible in the figure) wound on the outside of the wooden chamber. The cage is centered in the field which is directed axial to the wooden chamber.

A correct response was defined as a lever release during the 3-second stimulus period. An incorrect lever response occurred when the lever was released prior to the light stimulus or when the lever was released after the light stimulus had been automatically terminated. If the reinforcement programmer had stopped advancing and a correct response occurred, a pellet was dispensed. The programmer would also restart when the lever was released following automatic termination of the stimulus; however, no pellet would be delivered.

Each animal was given a 1-hour session daily except on weekends. Training occupied 27 sessions. The data presented in this report are based on sessions 28 through 64. The first twelve sessions (28 through 39) were run with the field off to establish a pre-exposure baseline. The next five sessions (40 through 44) were run at 45 Hz with a field intensity of 3 gauss rms. For the next five sessions (45 through 49) the frequency was changed to 7 Hz but was at the same field intensity of 3 gauss rms. Finally, the field was turned off, and 15 postexposure sessions were conducted.

The following data were recorded: time from illumination of the light panel to lever release, number of correct responses, total responses, body weight, and food intake.

## RESULTS AND DISCUSSIONS

The following three indices of performance were computed from the recorded data: reinforcement ratio, efficiency ratio, and reaction time.

Reinforcement ratio is the average number of correct responses required to receive one pellet. This ratio was always greater than one; however, it was possible to receive a pellet for each correct response if the intervals between lever depressions which produced stimuli were always greater than the longest time interval of the variable-interval reinforcement schedule. Efficiency ratio is defined as the ratio of correct responses to the total number of responses for one session. Reaction time is defined as the interval between onset of the light stimulus and release of the lever for all correct responses.

In the case of subject LE (Figure 2) the efficiency ratio increased steadily from session 28 through 43, while the reinforcement ratio for the same period did not change significantly. This trend is related to the finding that LE's incorrect responses were predominantly those in which she depressed the lever for periods extending beyond the duration of the light stimulus. She gradually reduced the duration of the lever depressions, thus increasing the efficiency ratio; but, since the correct responses were still interspersed among incorrect responses of the type which resets the variable-interval programmer, the reinforcement ratio did not improve significantly.

The average of LE's efficiency ratio was less for the 7-Hz period than for the 45-Hz period; however, the pattern of this variation does not indicate a field effect. The first two sessions of the 7-Hz period were consistent with previous trends. A discontinuity occurred between the second and third sessions, and a new trend was established which approached, in only three sessions, an extrapolation of the previous

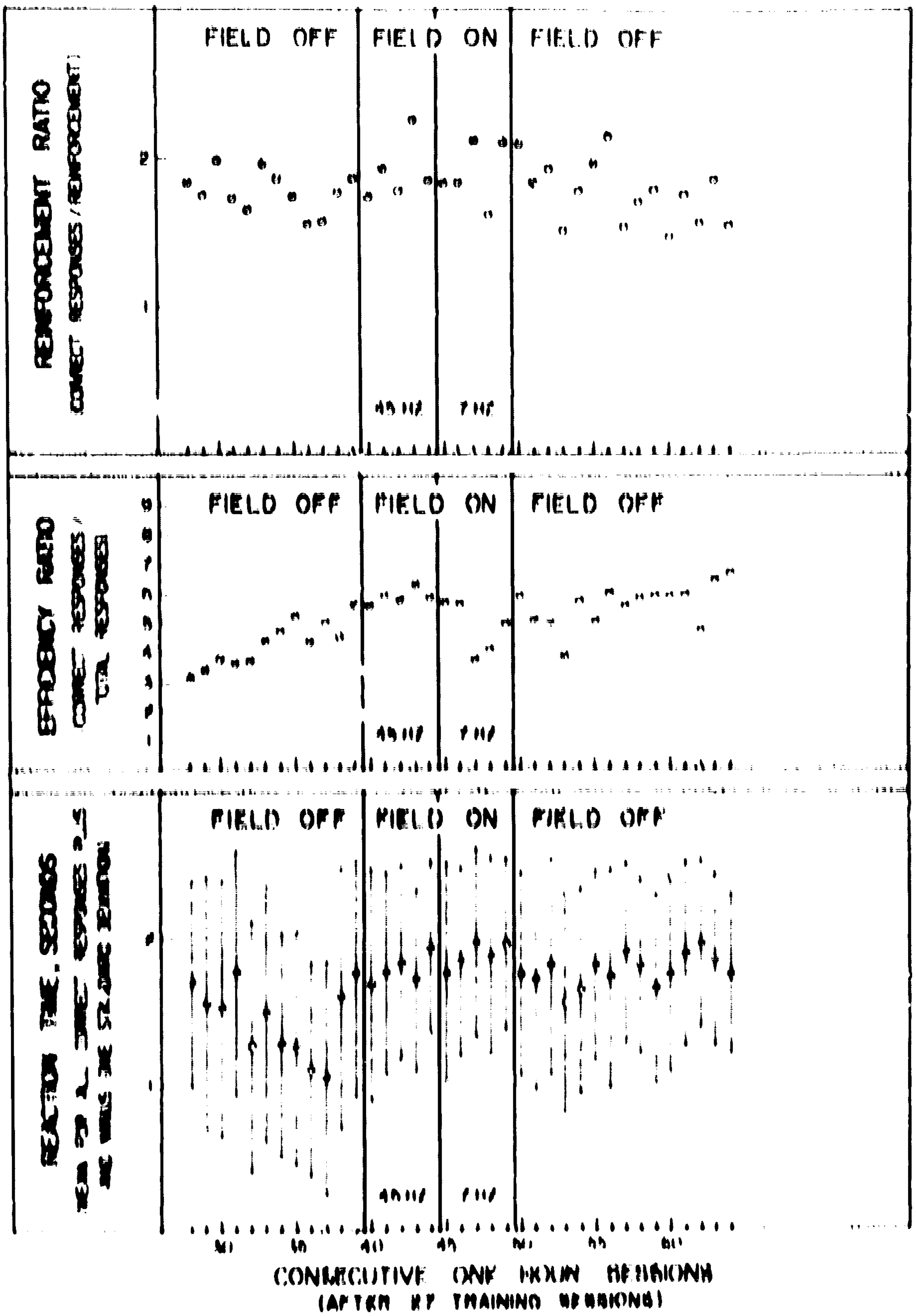


Figure 2

Performance Data for Subject [illegible]

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15